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ABSTRACT

This paper discusses Piagetian theory on children's cognitive development and its relevance to an early childhood science program. Children, at different stages of their development, exhibit characteristics of behavior or of thinking which may or may not affect how and what they learn in the classroom. It is suggested that subject-matter content, pedagogy, and instructional materials should be selected within the framework of the developmental needs of each learner. A consideration of how the preoperational child thinks and views reality has definite implications with respect to an early childhood science: curriculum must be child-centered and activity oriented and must provide children with a rich environment and the opportunity to explore that environment at their own pace, according to their individual cognitive abilities. (Author/BD)

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Piaget, The Young Child, and
Early Childhood Science Education

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Introduction

As adults, it is very difficult for us to think as the young child thinks - to see reality from the eyes of a three-, five-, or seven-year old. We cannot go back in time and remember our first thoughts when asked to predict which objects set before us would sink and which would float. When did we first realize that the tiny bean seed we had planted in April was the same as the lovely green plant we observed growing in May? Can anyone recollect when he or she truly understood that the number three was greater than the number two but less than the number four?

Indeed, the thinking of the adult is so different, so far more sophisticated, logical, and inflexible than the thinking of the young child that our task as educators of young children is a formidable one. We simply do not think in the same way the young child does. Yet how can we properly teach children unless we do know how they think, how their concepts of space, time, number, and cause and effect develop?

For too long, educators and classroom teachers in particular, have focused to such an extent on what to teach, how to teach, and with what to teach that they have forgotten whom they are teaching. All our efforts in teaching young children will be in vain unless we establish an appropriate framework in which that teaching will take place. Such a framework is and must be the developing child. Children, at different stages in their development, exhibit characteristics of behavior or of thinking which may or may not affect how and what they learn in the classroom. Subject-matter content and pedagogy are only appropriate when selected in relation

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to children's developmental levels of cognitive growth. We can no longer waste time in trying to make the foot fit the slipper as Prince Charming tried vainly to accomplish with Cinderella's unfortunate sisters. It is time for us to make the slipper fit the foot.

Such a task, even though it sounds simple enough, requires a thorough understanding on our part of how children think, what characteristics of thinking appear at different stages in their development, and how they view reality. The best description we currently have of how children's thought processes develop has been detailed for us in the monumental work of Jean Piaget, the giant of developmental psychology, as David Elkind has dubbed him. (1972, p. 9).

Preoperational Thought

Let us focus our attention on that stage of cognitive development which Piaget labels "preoperational" since the approximate age ranges for this stage, two or two and a half years to about seven years of age, encompass, in general, the early childhood years of the developing child.

To understand better Piaget's use of the term preoperational, we must first consider briefly what he means by an "operation". An "operation" is an interiorized action, a mental action characterized by flexibility, reversibility, and recognition that an object's appearance may change but not necessarily its amount, weight, or length. Such mental operations are indicative of logical thinking.

Thus, the preoperational thinker is simply not logical. He is pre-logical. What specifically characterizes his thinking?

1. His thinking is perception-bound, to use a phrase coined by Millie Almy and her associates in their significant study, Young Children's Thinking: Studies of Some Aspects of Piaget's Theory (1966). He can

only focus or center on one attribute or property of an object at a time, usually the most predominant attribute, for example, the object's size, shape, or color. Such "centering" prevents the child from noticing other features of an object.

2. The preoperational child's thinking is not reversible; he can only focus on the beginning or end state of a transformation, and not on the transformation itself. Given two balls of clay that the child establishes as equivalent in amount, when one ball of clay is transformed into the shape of a sausage, the child can no longer establish that equivalence. One piece of clay, probably the sausage-shaped piece, is perceived as longer and therefore the child generally concludes that it has more clay.

3. The preoperational child is unable to conserve. He is not able to recognize the invariance of a number of objects, even when their spatial arrangement is transformed. He also cannot compensate for changes in dimensions. When an equal amount of water is poured from a tall, narrow glass into a short, wide glass, the preoperational child does not recognize that a change in length is compensated for by a change in width. The preoperational child is not yet capable of performing these mental gymnastics.

For Piaget, the ability to conserve marks the gradual transition from thinking that is perceptually-oriented, largely intuitive, irreversible and inflexible to thinking that is logical, flexible, and reversible. Research has shown that this ability can appear anywhere between the ages of five and seven or eight.

4. Another relevant characteristic of preoperational thought is its egocentrism. The child views the world from one perspective, his

own. This egocentrism can lead to misinterpretations of natural phenomena. Chittenden (1970) cites an example used by Piaget of the young child who claims that the sun moves when he moves, "when one walks, it follows. When one turns round it turns round too" (p. 11). Egocentrism makes it difficult for a child to imagine how an object or scene might look when viewed from positions other than his own.

5. Two basic cognitive processes essential for the development of logical thinking are classification and seriation. The preoperational child is limited in his ability to classify. He lacks the ability to consider two attributes simultaneously, for example, shape and size or size and color; he has difficulty in recognizing that one object can possess several properties at the same time; he cannot combine subclasses (for example, red beads and yellow beads) into a larger class (wooden beads) or break down a larger class into its subclasses.

The preoperational child can seriate or order objects, on a trial and error basis, from shortest to tallest, thinnest to fattest, and so forth. Yet he lacks the ability to coordinate two variables simultaneously. In other words, if B is taller than A, but shorter than C, then B belongs between A and C. Such flexibility of thought is impossible during this stage of development.

The Preoperational Child's View of Reality

Up until this point, we have discussed general characteristics of children's thinking during the preoperational stage - centering, irreversibility, inability to conserve, and egocentrism. Let us turn our attention briefly to how young children, during this stage, interpret various natural phenomena - objects and events they encounter in their environment.

Research has shown that children are confused about the meaning of "aliveness". For the young child, anything that moves - a car, a cloud, branches on a tree - is alive. Things that don't move are not alive. Laurandeau and Pinard (1962) presented children with a list of familiar objects and asked them to group the objects into two categories, one for living things and one for non-living things. Their conclusions from their study supported Piaget's earlier findings that children below the age of nine or ten years experience some difficulty in correctly placing each item on the list in the appropriate category.

The concept of identity - the understanding that as an organism grows and changes over time, it still remains basically the same - is not easily understood by the preoperational child. Examples of changing organisms include the transformation of a seed into a plant which produces fruit containing new seeds; the metamorphosis of a caterpillar into a butterfly, a mealworm into a beetle.

Two of Piaget's colleagues, Gilbert and Vuyat (Piaget, 1973) tested children's understanding of the concept of identity by showing them a series of photographs of plants at various stages of growth. The children in their study had little difficulty recognizing two adjacent photographs as the same plant, but they did find it hard to believe that an early photograph in a series pictured the same plant as a later photograph in the same series.

Piaget's earlier studies of the young child's understanding of cause and effect relationships identified three basic characteristics that dominated the child's explanations of causality (Good, 1977). The first characteristic Piaget labeled "animism". Things such as the sun, the moon, trees, air, and the like act the way they do because they want to; they have

a consciousness and thus, can act voluntarily. Ronald Good (1977) records an interview of a young six-year old boy, Tom, who, when asked, "Where does the sun go at night?", responded, "It goes to sleep. And then the moon wakes up and it shines!" (p. 8).

The term "artificialism" was used by Piaget to describe the child's tendency to believe that things exist for man's benefit, because man needs them. In the case of Tom, when asked, "Where did the wind come from in the first place?" he answered, "Well, you see, God gave men air so they could breathe, and he wanted to help them out a little more. Like, you know sailboats? Well, the air moves them. The air pushes, and God helped us out so we could ride sailboats " (Good, 1977, pp. 8-9).

Lastly, Piaget used the term "magic" to characterize the child's explanation which made man the cause of natural phenomena.

Thus, the young child, until approximately the age of seven or eight, explains causality in terms of animism, artificialism, magic, or various combinations of each. Gradually, however, he progresses toward a more objective explanation of cause and effect relationships.

Implications for Early Childhood Science Education

What are the implications, then, that result from considering how the preoperational child thinks and views reality with respect to science education in the early childhood years?

Since the preoperational child's thinking is based on what he perceives in the here and now, concepts of natural phenomena must be developed through observation and manipulation of actual objects within the child's environment. Topics that include abstract concepts which are not within the realm of the child's immediate experience should not be included in an early childhood science curriculum. Good (1977), in examining sample first-grade science

textbooks, identified the following concepts related to a unit on weather as inappropriate for the cognitive abilities of a typical six-year old:

Water is always evaporating...
The cycle of evaporation and condensation is a result
of a heat exchange...
The weather cycle is related to the water cycle.

(p. 161)

Good also found, particularly in teachers' guides for the first grade, the following concepts taught under the broad topic of earth, moon, and sun system:

Day and night are caused by the rotation of the earth...
Planets, including the earth, revolve around the sun.
The sizes of the planets vary as do their relative
distances from the sun.

(p. 162)

Such concepts are truly abstract and demand of the child a thorough understanding of perspective, and relative position and motion. The preoperational child is incapable of such abstractions.

When a teacher does attempt to teach children something that is not familiar to them in terms of their own experiences, she must, of necessity, rely on teacher demonstrations and the use of models, diagrams, charts, and pictures to illustrate the concepts she is trying to teach. Because of the subjective, perceptually-oriented nature of the preoperational child's thinking, such teaching methods are questionable at this stage.

The young child's inability to think logically precludes any type of teaching which attempts to prove some principle through appeals to logic. Also, because the preoperational child cannot consider several variables simultaneously, David Elkind (1972) feels that "Instruction in controlled experimentation probably should not be introduced until adolescence when young people can deal with multiple simultaneous variations. The child must be able to cope with holding some factors constant while others are

systematically varied" (p. 10).

The implications are clear. Science instruction in the early childhood years should take into account the varying conceptual abilities of young children. How children think, and grow intellectually should be the major focus of early childhood educators as they plan science curricula appropriate for helping children learn about their world. What, then, should characterize an early childhood science curriculum?

An Early Childhood Science Curriculum

Although young children might be limited conceptually, there are no limits, unless we set them, to their curiosity, imagination, zest for learning, and interest in the many things about them. Experiences in "sciencing" (Neuman, 1972) not only satisfy their curiosity and interest, but also are the best vehicle for helping children make that important transition from thinking that is perception-bound, egocentric, illogical, and irreversible to thinking that is flexible, logical, reversible, and capable of conserving.

Science for young children is "finding out" about the world in which they live. As the relatively new Science-Five through Thirteen project describes it, "Exploration of the environment is certainly involved -- the examination of what is there.... There may be experimenting, there may be measuring, but much of the work will be finding out" (Schools Council, 1972, p. 5). How does the young child find out? The answer to this question is simple -- through investigations and explorations that involve concrete, "hands-on" experiences with objects and events in his immediate environment.

Why is such experience so important for the developing child? According to Piaget, experience builds upon experience. A child must be

able to actively relate something new in his experience to experiences previously encountered, assimilated, and stored as mental structures or understandings he has already acquired. Otherwise there is little chance of the child relating to, or understanding, a new experience.

For example, Johnny wants a cookie but the cookie jar is on top of the kitchen cabinet which he can't reach. How does Johnny accommodate himself to this problem? He has had previous experiences of climbing -- climbing the stairs, climbing the ladder on his outdoor jungle gym. He has also seen his father climbing a ladder to paint the kitchen ceiling. These previous experiences Johnny has assimilated into his understanding of "climbing". Yet there are no stairs available in the kitchen, nor any ladders. What does Johnny do? He accommodates himself to this new situation by looking for something he can use "to climb" to reach the cookie jar. He may use a kitchen chair, or stool, or perhaps a small step ladder might be handy. This process of finding a balance between something previously understood and something yet to be learned is called equilibration. For Piaget, it is one of the most important factors affecting cognitive growth.

Thus, a child with limited experiences with natural phenomena in his early years in school will undoubtedly have difficulty understanding new, but related phenomena encountered in later grades. For example, what will the child understand about magnetic fields surrounding the earth if his earlier experiences with magnets and magnetism has been limited? Will a child in second or third grade truly understand what is meant by the water cycle unless he already has experienced firsthand, and understands, the processes of evaporation and condensation? The role of experience in the early years of the young child cannot be overemphasized.

In direct experiences with the environment, the child is encouraged to use basic process skills which enable him to make sense out of these varied, hopefully challenging and interesting experiences. Four such processes include observing, predicting, classifying, and communicating.

Piaget's work implies that the fine art of observation is the most important skill to be developed in young children as they experience reality (Elind, 1972). Neuman (1972) points out that "Observing is the fundamental building block for all of the other processes and thus must be stressed in every way possible throughout all of the various activities carried out in sciencing" (p. 218). Observation, however, is much more than a superficial examination of an object accompanied by a one or two word description. Observation means a total involvement of the child, using all his senses, in finding out about an object -- its properties and how it reacts under varying circumstances. To do this, the child must act upon the object.

For example, in learning about the properties of water, the child doesn't just taste water, he feels water; he listens to water dripping, splashing, gurgling; and he sees how water reacts under various circumstances - water takes the shape of its container, water flows through some materials and not through others, water dissolves some substances but not others.

In his observations the young child must be encouraged to note how objects are alike and different. Thus, he makes comparisons between seeds, leaves, shells, rocks, and various other objects found in his immediate environment. In making such comparisons, the child is acting upon the objects; he is looking, touching, tasting, smelling, and listening. Such knowledge, knowledge that comes from the object itself, is called physical knowledge by Piaget, and is the foundation upon which intelligence develops. Careful, detailed observations help develop such knowledge.

The second process to be considered is predicting. Children enjoy making predictions as it appeals to their curiosity and their enjoyment of anticipating what will happen. Giving the child opportunities to make predictions about "what would happen if" helps him to accommodate his thinking to new experiences. In floating and sinking activities, the child is asked to predict whether a large styrofoam ball will float or sink. The young child, bound by his perceptions, might say that such an object will sink "because it's big". The size of the object dominates his thinking. Yet, when he places the ball in the water, it floats. How does he accommodate himself to this unexplained phenomenon? He is confused in his thinking. Through further exploring, question-asking, and discovering, however, he is soon able to accommodate his thinking about "floating and sinking" so that the factor of weight, not only of size, begins to emerge as an important factor in causing some objects to sink and others to float.

There are many opportunities available in the child's day to day explorations of his environment where he can be asked to predict what might happen under certain circumstances. Such opportunities must be utilized to help each child discover new relationships and develop further understandings on his own. The emphasis should always be on the prediction; the necessary explanations can come later.

During their investigations of science-related phenomena, children should utilize another important process skill, that of classifying - grouping or sorting objects according to some common property. Even though the preoperational child can group objects on a perceptual level only, such an ability precedes higher level classification skills. The knowledge that the child acquires as he groups objects according to his own classification scheme is logico-mathematical knowledge which Piaget distinguishes from

physical knowledge. Physical knowledge is knowledge derived from the objects themselves - their properties and how they react under varying circumstances or stimuli. Logico-mathematical knowledge, however, is knowledge which results from the child's own actions on objects. Combining, taking apart, and arranging in some kind of order are examples of these types of actions. In this type of activity the properties of each object are not as important as the relationships the child constructs himself between and among the objects. Such knowledge is called logico-mathematical knowledge because it is knowledge that fosters the development of logical thought. Numerous opportunities for classifying objects present themselves in an early childhood science curriculum: classifying sounds (higher-lower; louder-softer; pleasant-unpleasant); classifying animals (tame-wild; furry-nonfurry); classifying leaves according to color, shape, size, number of veins, and so forth.

A major feature of any early childhood education program should be that it provide children with numerous opportunities for communicating - with each other, with their teacher, or with some other adult in the classroom. This is the fourth and last process briefly considered in this paper. Communicating is not only important for language development, but also for intellectual development in general. Piaget has remarked that "experience is always necessary for intellectual development", but such experience should include not only physical activity but social interactions as well (1964, p. 31). We have already remarked that the preoperational child is egocentric; he views reality from one viewpoint, his own. With increased opportunities to interact with his classmates, share his viewpoints and listen to theirs, the preoperational child will begin to realize that there are viewpoints other than his own; that

there are different ways of looking at the same reality. Such understandings will help the child in his transition from egocentrism to operational thought.

An early childhood science program, then, can be described as child-centered and activity-oriented; one that provides children with a rich environment and the opportunity to explore that environment at their own pace and according to their individual cognitive abilities. In their active explorations, children should be encouraged to observe carefully, note similarities and differences, make predictions, test out their predictions, ask questions, and interact with one another and with the teacher. They should be constantly encouraged to think and talk about what they are doing and seeing. Not only will children be learning science; they also will be engaging in experiences which will develop their ability to think logically and systematically.

Such child-centered, activity-oriented programs already exist. The Science Curriculum Improvement Study (SCIS), the Elementary Science Study (ESS), and Science - A Process Approach (S - APA), are several such programs. To some extent Piagetian theory has influenced each of these programs in their development. They offer the classroom teacher an abundance of suggested activities and materials to use in involving children in experiences with science phenomena. However, the classroom teacher must carefully adapt these pre-packaged programs to the developmental needs of her students. One of the newest such programs, Science Five through Thirteen, best describes the relationship between children's stages of development and the kinds of science experiences they should be engaged in. It is a practical guide in terms of how the classroom teacher can plan activities and experiences suitable for children at varying stages of development.

Conclusion

Any teaching, to be effective, must be carried out within the framework of basic principles of child development. The child, at each stage in his development, must be the teacher's main concern, rather than content, methodology, and materials. For at least a decade, this need - the need for adapting instruction to the developmental needs of the learner - has been voiced in numerous speeches, publications, workshops, and college seminars. Yet this basic need still remains unmet in many classrooms throughout the country today.

We must continuously voice this need to our colleagues; we must begin to work together to see that the fulfillment of this need becomes a reality - not tomorrow, but today.

This paper has attempted to show how this need can be fulfilled in the teaching of science in the early childhood years. What has been said holds true for other areas of the curriculum - reading, mathematics, social studies.

We owe a tremendous debt of gratitude to Jean Piaget. He has opened up for us the world of the young child's mind. We, as educators, should thank him for another reason as well. He has made us reflect on the relevance of contemporary pedagogical theory and practice; this reflection has made us refocus our attention on that which should be most important of all to us - the child. Thank you, Jean Piaget.

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